International Journal of Latest Research in Engineering and Science
Volume 1 | Issue 1 | May 2015

Optimal Distributed Generation Siting and Sizing by Considering Harmonic Limits using SLPSO

T. Abinaya [1] and R. M. Sasiraja [2]

[1]PG Scholar, Department of EEE, Anna University Regional Office, Madurai, Tamilnadu, India
[2]Faculty, Department of EEE, Anna University Regional Office, Madurai, Tamilnadu, India

Article Info

Article history:

Received on 4th May 2015
Accepted on 9th May 2015
Published on 19th May 2015

Keyword:

Distributed Generation,
Harmonic Distortion,
Decoupled Harmonic Power Flow,
Particle Swarm Optimization.

ABSTRACT

Distributed Generation (DG) units are also called as Decentralized Generation and Embedded Generation. The objective is to maximize the DG penetration level, minimization of loss by optimally selecting types, locations and sizes of utility owned DG units. The DG penetration level could be limited by harmonic distortion because of the nonlinear current injected by inverter-based DG units and also protection coordination constraints because of the variation in fault current caused by synchronous-based DG units. Hence the objective is to maximize DG penetration level from both types of DG units, taking into account power balance constraints, total harmonic distortion limits, and protection coordination constraints. The Social Learning Particle Swarm Optimization (SLPSO) algorithm is used to maximize the overall DG penetration level and the proposed system is tested in the IEEE-30 bus system.

Corresponding Author:

T.Abinaya,
PG Scholar, Department of EEE,
Anna University Regional Office,
Madurai 7, Tamil Nadu, India
E-mail: abinayatamizhan@gmail.com

I. INTRODUCTION

DG generally refers to small-scale (typically 1 kW – 50 MW) electric power generators that produce electricity at a site close to customers or that are tied to an electric distribution system [1]. Optimal DG placement (ODGP) can improve network performance in terms of voltage profile, reduce flows and system losses and also improve power quality and reliability of supply. The DG units are of two types namely utility owned DG units and customer owned DG units [2]. In the case of a utility owned DG installation, the utility has to optimally plan the location and size of the DG units in order to improve network benefits and reliability [3]. In the case of customer owned DG installation, the utility planner should conduct feasibility and assessment study to evaluate any technical issues resulting from the new installation of customer owned DG installation [4].

A new optimization approach that employs an Artificial Bee Colony (ABC) algorithm to determine the optimal DG units size, power factor and location in order to minimize the total system real power loss [5]. The closed form equations are used for determining allowable penetration levels of DG resources [6]. The effect of DG on coordination will depends on the size, type, and placement of DG. The paper [7] explores that the effect of high DG penetration on protective device coordination. The advantages of installing DG in distribution systems are improving reliability, mitigating voltage sags, unloading sub transmission and transmission system [8].

In [9] the harmonic filter planning is presented as a combinational optimization problem, which is solved using Genetic Algorithms. Here the current injection method is used to determine the harmonic flow in a radial distribution feeder. In ref [10] a fuzzy-based approach for optimal placement and sizing of fixed capacitor banks in radial distribution networks in the presence of voltage and current harmonics.

A new method, based on interactive Multi Objective Nonlinear Programming (MONLP), using Genetic Algorithms (GAs) to study passive filter planning [11]. When the system condition changes, the passive filters may be most likely to cause other power quality problem or have less impact on mitigation of harmonics. An analytical approach [12] is used to minimize the system losses by installing various types of DG units and finding optimal size and power factor of four types of distributed generation (DG) units.

PSO is being used to evolve not only the network weights, but also the network structure. The method is so simple, efficient and this approach is effective for any network architecture [13]. The particle swarm optimizer has been found to be robust and fast in solving nonlinear, non-differentiable, multi-modal problems.

II. PROBLEM FORMULATION

The objective of this problem is to maximize the DG penetration level, by selecting the optimal size of inverter based DG units, using Particle Swarm Optimization (PSO) algorithm. The constraints of the problem include bus voltage limits, individual harmonic limits, total harmonic limits and power balance constraints.

A. Objective function:

The main objective is to maximize the DG penetration level with respect to total system capacity. The objective function F can be defined as follows:

$$\text{Maximize F (\%)} = \frac{\sum_{i=1}^{Nbus} P_{DG,i}^{inv}}{TotalMVA} \times 100 \quad (1)$$

$$\text{Minimize } P_L = \sum_{i=1}^{N} Loss_i \quad (2)$$

B. Equality Constraints:

The power balance constraints at fundamental frequency for each bus i can be given as follows:

$$P_{G,i} + P_{DG,i}^{inv} - P_{D,i} = \sum_{j=1}^{Nbus} |v_i^{(1)}||v_j^{(1)}||y_{i,j}^{(1)}| \cos(\theta_{i,j}^{(1)} - \delta_i^{(1)} + \delta_j^{(1)}) \quad (3)$$

$$Q_{G,i} + Q_{DG,i}^{inv} - Q_{D,i} = \sum_{j=1}^{Nbus} |v_i^{(1)}||v_j^{(1)}||y_{i,j}^{(1)}| \sin(\theta_{i,j}^{(1)} - \delta_i^{(1)} + \delta_j^{(1)}) \quad (4)$$

C. Inequality Constraints:

Total Harmonic Distortion Limits

The total voltage harmonic distortion at each bus i is as follows:

$$THD_{v,i}(\%) = \frac{\sqrt{\sum_{h=2}^{h_{max}} |v_i^{(h)}|^2}}{|v_i^{(1)}|} \times 100 \le THD_v^{max} \quad (5)$$

where THD_v^{max} is the maximum permissible total voltage harmonic distortion which is usually set at 5%.

D. Protection Coordination:

An inverse time over current characteristics is considered for the OCR relays as given in the following:

$$t_{ij} = TDS_i \frac{A}{\left(\frac{I_{SC,ij}}{I_{pi}}\right)^B - 1} \quad (6)$$

Where,

A & B are constants that depend on the type of OCR characteristics.

TDS_i is the time dial setting of OCR.

$I_{SC,ij}$ is the short circuit fault current flowing through the relay i because of fault at location j.

I_{pi} is the pickup current of the relay i above which it starts operating.

III. Social Learning Particle Swarm Optimization

In 1921, some British birds were first seen to open milk bottles in the small town of Swaythling. In the following 25 years, such observations had been continually reported from numerous other sites spreading all over the Great Britain and even some other areas in the European continent. This is the first evidence of social learning, where the birds are believed to learn to open milk bottles by observations and interactions with other birds, instead of learning by themselves.

During the past decades, various mechanisms have been proposed and discussed in social learning theory, e.g., stimulus enhancement and local enhancement, observational conditioning, contagion and social facilitation. Among these mechanisms, the most interesting social learning mechanism is imitation, which is considered to be distinctive from other social learning mechanisms, because imitation, which operates across a whole community, could lead to population- level similarities of behavior such as culture or tradition. Such population-level similarities may imply convergence of a dynamic system, thus providing its essential applicability in an evolutionary algorithm [14].

Inspired by social learning mechanism, an imitator will learn the behaviors of different demonstrators in the following manner:

$$X_{i,j}(t+1) = \begin{cases} X_{i,j}(t) + \Delta X_{i,j}(t+1) & if\ P_i(t) \le P_i^L \\ X_{i,j}(t) & otherwise \end{cases} \quad (7)$$

where $X_{i,j}(t)$ is the j-th dimension of particle i's behavior vector in generation t, with $i \in \{1,2,3,4 \ldots \ldots m\}$ and $j \in \{1,2,3,4 \ldots \ldots n\}$; $\Delta X_{i,j}(t+1)$ is the behavior correction. Taking into account the fact that in a society, the motivation to learnfrom better individuals may vary from individual to individual (typically, better individuals are less willing to learn from others), we define a learning probability PLi for each particle i. The flowchart of SLPSO algorithm is depicted in Fig 1.

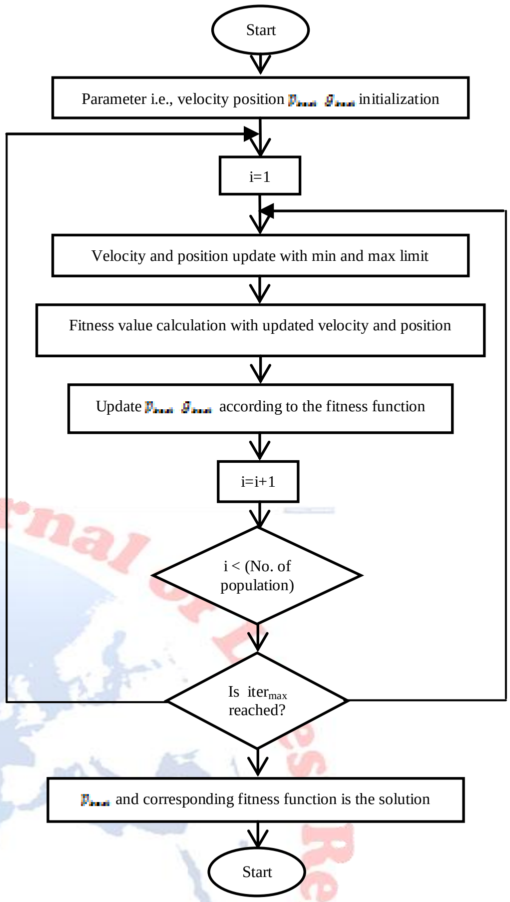

Figure 1: Flowchart of SLPSO

The particle i will learn (correct its behavior vector) only if a randomly generated probability pi satisfies $0 \le P_i(t) \le P_i^L \le 1$. In detail, $\Delta X_{i,j}(t+1)$ is generated as follows:

$$\Delta X_{i,j}(t+1) = r_1(t).\Delta X_{i,j}(t) + r_2(t).I_{i,j}(t) + r_3(t).\epsilon.C_{i,j}(t)$$

$$\begin{cases} I_{i,j}(t) = X_{k,j}(t) - X_{i,j}(t) \\ C_{i,j}(t) = X_j(t) - X_{i,j}(t) \end{cases} \quad (8)$$

The swarm size m be determined as a function of the search dimensionality in the following form:

$$m = M + \left[\frac{n}{10}\right] \quad (9)$$

where M is the base swarm size for the SL-PSO to work properly.

IV. Results and Discussion

The proposed problem of maximizing the DG penetration level is implemented in MATLAB and tested in IEEE 30 bus system. In this work, the population size is set to 20 and the maximum number of iterations is set to 100. The single line diagram of IEEE 30 bus system is

depicted in Fig. 2. This network has six generators, 21 loads and 41 branches.

For IEEE 30 bus system the following assumptions are observed in this approach.

- The boundaries of bus voltage limits are set at 0.95 and 1.05 p.u., respectively.
- The maximum numbers of DG units are taken as 12.
- The minimum and maximum values of DG units are limited between 0.1 – 5 MW, respectively.

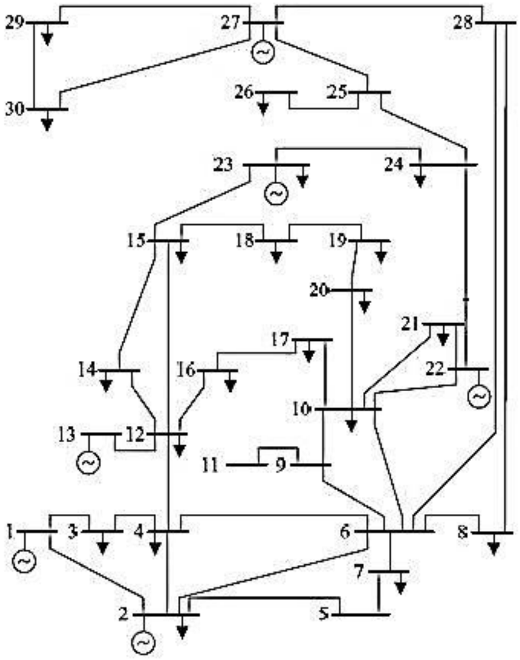

Figure 2: Single line diagram of IEEE 30 bus system

Base case load flow is performed and corresponding values of system power flows, bus voltages and line losses of test systems are observed. The bus corresponding to the minimum THD value is identified as optimal location of DGs. Hence, among all the calculated THD values the minimum 12 THD values are considered and their corresponding buses are identified as optimal locations for placing DGs. After finding these optimal locations, the efforts are focused towards the finding of optimal capacity of DGs, to be connected in these preferred locations, with the help of SLPSO algorithm. The optimal location and size of DG units are tabulated below in Table 1.

Table 1: Optimal location and size of IEEE 30 bus system

Total No of DGs	Optimal Location	DG sizes in MW
1	28	4.9887
2	5	4.7180
3	6	4.9687
4	9	4.9674
5	11	4.7298
6	15	4.4436
7	10	4.6379
8	12	4.8246
9	4	4.9143
10	16	3.9471
11	18	4.9204
12	20	4.7344

An optimal penetration level of 60.7950% is obtained for IEEE 30 bus system using SLPSO algorithm. The improved voltage profile after placing the DGs optimally is shown in Fig. 3.

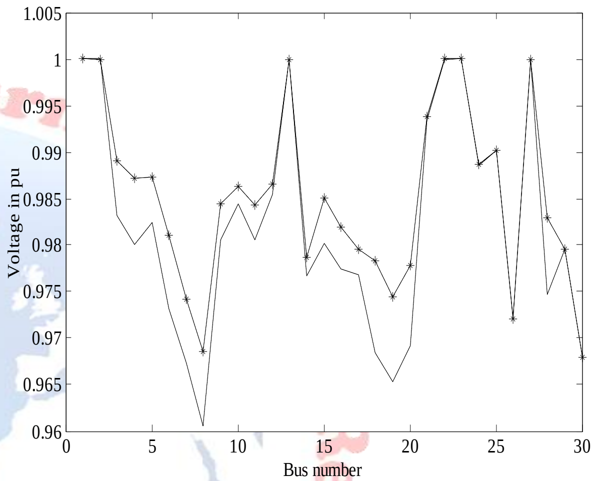

Figure 3: Voltage profile improvement of IEEE 30 bus system

Consider the three phase fault is occurred at location 6, then the fault current flowing through the bus is 9.6139 p.u., There are 6 relays are used for protection coordination, one is primary relay and other 5 relays are backup relays. If the fault is occurred at location 6, then the primary relay is used to detect the fault. If the primary relay is fails to operate then the backup relay is used to detect the fault with minimum operating time to protect the system from damage. The primary and backup relays opreting time is tabulated below in Table 2 and Fig. 4.

Table 2: Operating time of primary and backup relays

Fault Location	Operating times of relay in sec (p=primary, b=backup)					
	p	b1	b2	b3	b4	b5
F6	0.2600	0.7083	1.3291	2.0120	2.7632	3.5896

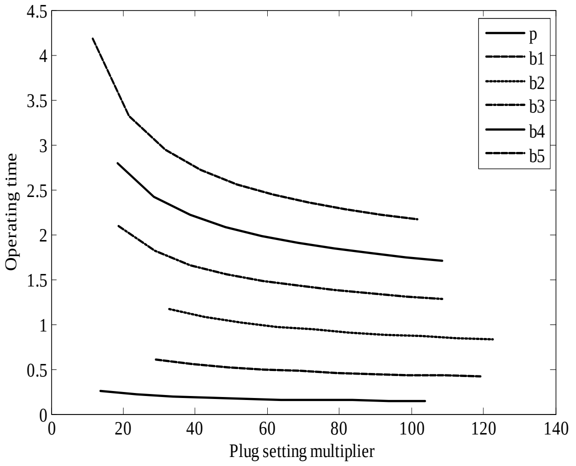

Figure 4: Primary and Backup relay operating times

The comparison of real power losses without and with DG for IEEE 30 bus system is tabulated in Table 3. After placing the DGs, the real power loss is reduced from 2.4438 MW to 1.6772 MW. In this case, the values of percentage reduction in real power losses are nearly 31.3696%.

Table 3: Comparison of losses for IEEE 30 bus system

Losses without DG in MW	Losses with DGs in MW	Reduced Losses in %
2.4438	1.6772	31.3696

V. Conclusion

This method of optimal placement and capacity of DGs using the SLPSO has been implemented for 30 bus system. The improper location and incorrect size of DG units can cause major disturbances in power system network. The DG penetration level is limited by fault current levels, protection coordination of relays, harmonic distortion, stability and power quality.

The objective of the proposed optimization problem is to maximize the DG penetration level and loss minimization subject to power balance constraints and total harmonic distortion limits. The result shows that the maximum DG penetration level is limited by harmonic distortion level. Therefore, in this paper the bus corresponding to the minimum value of THD is identified as optimal location of DGs for the improved voltage profile and reduced losses in the systems. The proposed optimization method can serve as a good planning tool for the utility operator to optimally allocate DG of different types in order to achieve better penetration level.

Acknowledgements

The authors are very thankful to the authorities of Anna University Regional Office Madurai providing all the necessary facilities and a motivating support towards this research.

References

[1] N. Jenkins, R. Allan, P. Crossley, D. Kirschen, and G. Strbac, "*Embedded Generation*," Institution of Engineering and Technology, 2008.

[2] A. Algarni and K. Bhattacharya, "Utility-owned DG units' impacts on distribution system operation," in *Proc. IEEE/PES Power Systems Conf. Expo., PSCE'09*, Mar. 2009, pp. 1–6.

[3] A. Schwarzenegger, "Renewable distributed generation assessment: Sacramento municipal utility district case study," *Utility Project Report*, 2005.

[4] L. Luna and E. Parra, "Feasibility assessment of distributed generation interconnection," in *Proc. IEEE Trondheim Power Tech. 2011*, Jun. 2011, pp. 1–7.

[5] F. Abu-Mouti and M. El-Hawary, "Optimal distributed generation allocation and sizing in distribution systems via artificial bee colony algorithm," IEEE Trans. Power Del., vol. 26, no. 4, Oct. 2011, pp. 2090–2101.

[6] A. Bhowmik, A. Maitra, S. Halpin, and J. Schatz, "Determination of allowable penetration levels of distributed generation resources based on harmonic limit considerations," IEEE Trans. Power Del., vol. 18, no. 2, Apr. 2003, pp. 619–624.

[7] S. Brahma and A. Girgis, "Development of adaptive protection scheme for distribution systems with high penetration of distributed generation,"IEEE Trans. Power Del., vol. 19, no. 1, Jan. 2004, pp. 56–63.

[8] N. Nimpitiwan, G. T. Heydt, R. Ayyanar, and S. Suryanarayanan, "Fault current contribution from synchronous machine and inverter based distributed generators," IEEE Trans. Power Del., vol. 22, no. 1, Jan. 2007, pp. 634–641.

[9] F.Pamplona and B. Souza, "Harmonic passive filter planning in radial distribution systems using genetic algorithms," in Proc. IEEE/PES Transmission and Distribution Conf. Expo.: Latin America, Nov. 2004, pp. 126–131.

[10] M. A. S. Masoum, A. Jafarian, M. Ladjevardi, E. F. Fuchs, and W. M. Grady, "Fuzzy approach for optimal placement and sizing of capacitor banks in the presence of harmonics," IEEE Trans. Power Del., vol. 19, no. 2, Apr. 2004, pp. 822–829.

[11] El-Zonkoly, "Optimal placement of multi-distributed generation units including different load models using particle swarm optimisation,"IET Gen., Transm., Distrib., vol. 5, no. 7, Jul.2011, pp. 760–771.

[12] D. Q. Hung, N. Mithulananthan, and R. C. Bansal, "Analytical expressions for DG allocation in primary distribution networks," IEEE Trans.Energy Convers., vol. 25, no. 3, Sep. 2010, pp. 814–820.

[13] Eberhart and Y. Shi, "Particle swarm optimization: Developments, Applications and resources," in Proc. 2001 Congr. Evolutionary Computation,2001, vol. 1, pp. 81–86.

[14] Ran Cheng, Yaochu Jin, "A social learning particle swarm optimization algorithm for scalable optimization," Department of Computing, University of Surrey, Guildford, Surrey GU2 7XH, United Kingdom.

[15] V. Ravikumar pandi, H. H. Zeineldin and Weidong Xiao, May 2013 "Determinin Optimal Location and Size of Distributed Generation Resources Considering Harmonic and Protection Coordination Limits", IEEE Transactions on Power Systems., vol. 28, no. 2, pp.1245-1254.

Author Profiles:

R. M. SASIRAJA obtained B.E. degree in Electrical and Electronics Engineering in 1996 from Madurai Kamaraj University and M.E. in Power Systems Engineering from Anna University Chennai in 2007. Currently, he is working as a Faculty in the Department of Electrical and Electronics Engineering of Anna University, Regional Office, Madurai. He is pursuing Ph.D. in the area of Distributed Power Generation. His area of interest includes Distributed Generation, Smart Grid, Soft Computing Techniques applied to Power Systems, Energy Audit, and Conservation in Industries. He is life member of Institution of Engineers, Kolkata.

T.ABINAYA received B.E. degree in Electrical and Electronics Engineering from University College of Engineering, Tiruchirappalli (Ariyalur campus), Chennai, India in 2013 and currently he is pursuing M.E. degree in Power Systems Engineering from Anna University Regional Office Madurai, India. His research interest includes Distributed Generations, Renewable Energy Sources, and Soft Computing Techniques applied to Power Systems.